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100 Femtosecond Laser Absorption in Solid Density Targets

D. F. Price
R. M. More
R. S. Walling
R. E. Stewart

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Dwight F. Price, R. M. More, R. S. Walling, R. E. Stewart

Lawrence Livermore National Laboratory
P.O. Box 808 Mail Stop L-251
Livermore, California 94550
Phone (510) 423-6170 Fax (510) 422-2253
E-mail price4@llnl.gov

1. Introduction

Experimental short pulse lasers are rapidly approaching energy levels where target irradiances exceeding 10^{20} W/cm^2 are routinely achievable [1,2,3]. These high intensity levels will open up a new class of solid target interaction physics where relativistic effects must be included and non-traditional absorption mechanisms become significant. However much remains to be understood of the absorption physics at lower intensities where classical absorption is dominated by collisional and resonance absorption. If attention is paid to producing clean laser pulses that do not significantly pre-pulse interact with the target, it is possible to produce plasmas of sufficiently short scale length that near-solid density interactions are observable at intensities exceeding 10^{18} W/cm^2 for 100 fs laser irradiation.

We report here extensions to our previous efforts at normal incidence [4] that expand our observations to non-normal angles including the effect of polarization for several target materials. Between 10^{13} W/cm^2 and 10^{14} W/cm^2 we observe that the target absorption retains a signature of the intra-band atomic transitions. At higher intensities a more material independent ion-electron collisional absorption and short scale length resonance absorption dominate. P - polarized absorption in short scale length plasmas has been observed to exceed 60 percent.

2. Experiment

The experiment was performed on the 100 fs Ti:Sapphire laser of the USP facility at Lawrence Livermore National Laboratory. The Ti:Sapphire laser is capable of delivering 1 joule at 800 nm onto a target at intensities of 5×10^{19} W/cm^2 with a 1.5

times diffraction limited focus. In order to produce as low a level of prepulse as possible the current set of experiments where performed with frequency doubled 400 nm light. The pulse contrast is 10^{-7} one picosecond prior to the peak of the pulse; allowing near-solid density experiments to be performed. The compression of the CPA pulse, its frequency doubling, and transport to the target are performed at vacuum. The light is focused with an off-axis parabolic mirror at f/4.8. Third order correlations are made on all shots to determine the pulse width used. Typical pulse widths are 120 fs to 130 fs.

The target, consisting of 1 micron thick e-beam deposited thin films on 1.5 mm thick glass plates, is raster scanned to ensure clean undamaged surface material on each shot. Intensity is varied by defocusing the target. The reflected, incident, transmitted, and back scattered light are measured on cross calibrated pyro-electric meters. Scattered light is monitored by an array of optical diodes, which are calibrated by the use of a Lambertian scatter of known scattering efficiency.

3. Observations and Conclusions

Observation were made in 10 degrees increments between 12.5 and 72.5 degrees angle of incidence. Both s and p - polarization where used. Absorption was inferred to be:

Absorption = 1 - Reflected - Transmitted - Scattered - Back Scattered

The previous results at 0 degrees angle of incidence agreed well with the low angle 12.5 degree shots, but significant improvement in absorption efficiency was noted for p - polarized light with increasing angle of incidence. This increase in absorption is due to resonance absorption in a short scale length expansion plasma. Unlike long scale length absorption, no notable maximum is observed in the p - polarized reflectivity (Figure 1.) up to the 72.5 degree limit of these experiments. The s - polarized absorptivity is observed to decrease with angle.

Considerable success has been achieved with simple non-hydrodynamic models of the plasma assuming resonance absorption and collisional absorption by varying the plasma expansion scale length and dielectric properties to achieve best fit. Improvements are expected when this absorption model is incorporated into a fully hydrodynamic model with wave-solving capabilities.

Previous experiments suggest that at intensities greater than 10^{16} W/cm^2 the s- and p - polarized light would reflect from the electron-ion "plasma mirror" with a nearly material independent reflectivity. We have investigated the atomic Z dependence of the absorption in the high intensity regime and find that absorption increases with Z and is well modeled by our hydrodynamic calculations including resonance and collisional absorption.

Our future plans are to extend this work to higher intensities where non-classical absorption mechanisms become important.

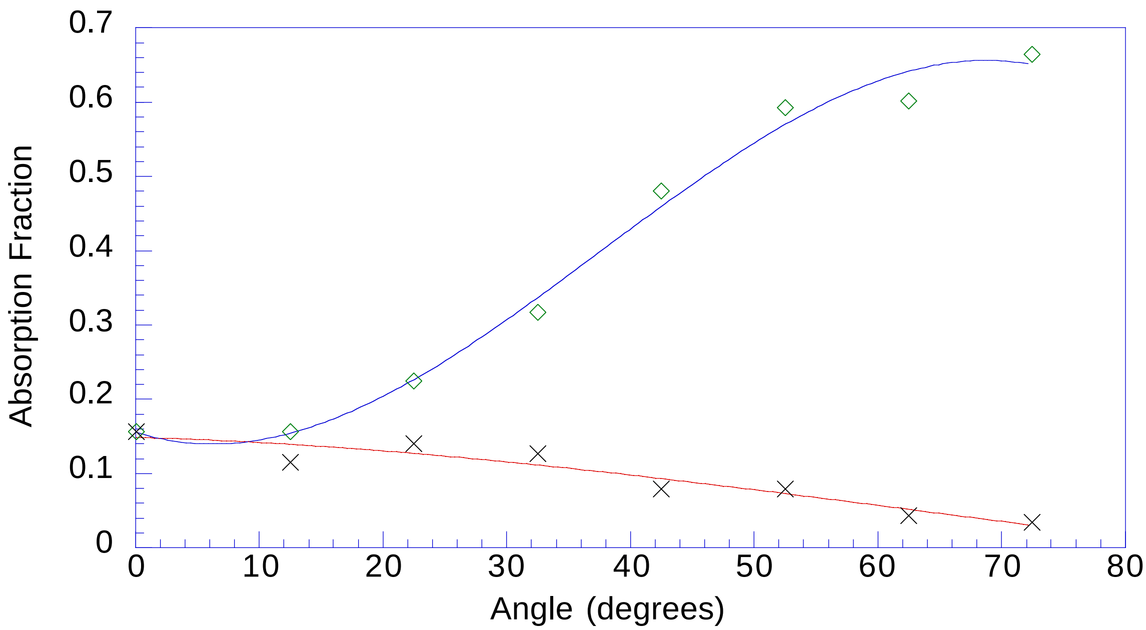

Figure 1. The experimental results for s and p - polarized absorption at 10^{16} W/cm^2 suggest that resonance absorption in short scale length plasmas plays a dominant role at high angles for p - polarized light. s - polarized (X symbol); p - polarized (diamond symbol).

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